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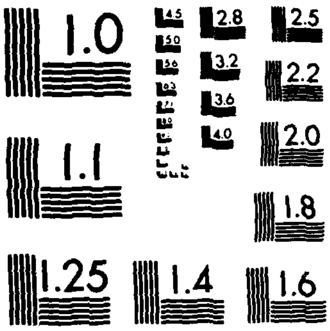

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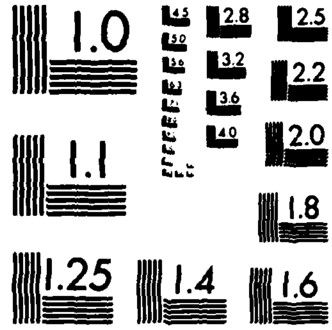

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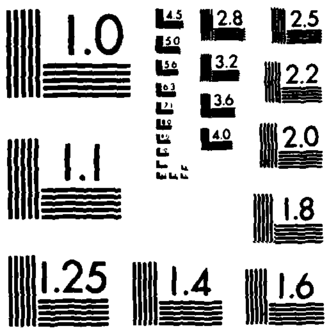

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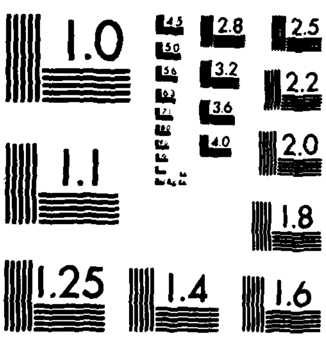

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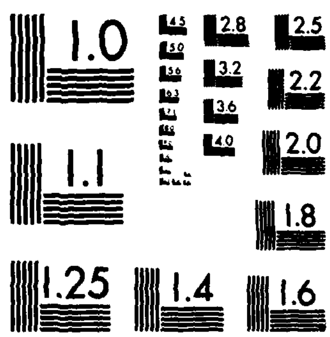

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ADVANCES IN THE MEASUREMENT OF PERSONNEL PRODUCTIVITY

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CENTER FOR NAVAL ANALYSES

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Determination of trade-offs between personnel with different characteristics is vital to attaining a high ratio of personnel productivity to costs. Personnel trade-offs are evaluated using unit performance, individual performance, and survey data as measures of productivity. For each approach, previous work is briefly reviewed, then models for improving productivity measurement are presented. Broad-based proposals are made for advancing personnel productivity measurement in the Navy.

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2. This Research Contribution is the final report of a CNA-initiated study on the productivity of enlisted personnel. The consensus of over 100 military and civilian manpower experts at a recent CNA conference on Navy manpower research was that the highest priority belongs to this issue. The objective is to achieve a high ratio of personnel productivity to costs in the process of personnel distribution and manpower requirements determination. Three avenues of productivity research are explored in enclosure (1), and proposals are made for advancing personnel productivity measurement in the Navy.

3. Research Contributions are distributed for their potential value in other studies and analyses. The enclosure does not necessarily represent the opinion of the Department of the Navy.

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ABSTRACT

Determination of trade-offs between personnel with different characteristics is vital to attaining a high ratio of personnel productivity to costs. Personnel trade-offs are evaluated using unit performance, individual performance, and survey data as measures of productivity. For each approach, previous work is briefly reviewed, then models for improving productivity measurement are presented. Broad-based proposals are made for advancing personnel productivity measurement in the Navy.

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THE IMPORTANCE OF PERSONNEL PRODUCTIVITY MEASUREMENT

The Navy seeks to employ personnel in ways that maximize productivity. To this end, research has been conducted on workload forecasting [1], training programs [2], and other topics related to efficient personnel management. While these analyses are of value to the Navy, they provide little information about potential manpower trade-offs among different types of personnel to achieve a high ratio of productivity to costs.

In the next decade, a declining youth population will raise the cost of new recruits. The planned expansion of the fleet will require increased manpower levels. And the trend toward more complex equipment will demand more technically skilled personnel. The Navy must be in a position to adjust to these changes. To do so, it needs a more-flexible system of determining manpower requirements, one that allows both cost and productivity to be taken into account. Consequently, research is needed on trade-offs among careerists and recruits, higher quality and lower quality personnel, and different skill mixes. This research is difficult to do [3], but the payoff in improved productivity to costs is potentially very large.

Studies of personnel trade-offs use three types of methodologies. The first relates operational data on unit performance to the characteristics of unit personnel. The second relies on surveys of the relative performance of individuals or of the performance of an "average" individual of a certain kind. The final type relates measures of individual performance to the characteristics of individuals.

We now turn to detailed discussions and examples of these three types of personnel productivity studies. Although they all have drawbacks, at the same time they offer a promise for advancing the measurement of personnel productivity. Then, we will propose methods for relating productivity to personnel characteristics and examining trade-offs among personnel of different types. They should form a basis for more efficient distribution of personnel and determination of manpower requirements.

PERSONNEL PRODUCTIVITY MEASURED BY UNIT PERFORMANCE

PREVIOUS WORK

CNA has analyzed the effects of personnel characteristics on ship performance. Studies of Operational Readiness Inspection scores [4] and Casualty Reports [5] have found positive effects of personnel quality and skill level on unit performance. They did not examine possibilities of substitution between different types of personnel, and the results were too limited to be used directly for personnel assignment or developing manpower requirements. Nonetheless, they took the right line of inquiry.

For example, the Maintenance Personnel Effectiveness Study [· related crew characteristics by rating to the condition of variou subsystems — boilers, engines, gun systems, missile systems, ant: submarine warfare (ASW) systems, and sonars. The two factors tha consistently affected equipment condition were average paygrade o and equipment complexity. Crew size and length of service were a. influential factors for most ratings.

The following steps can be investigated for improving the maintenance personnel effectiveness model:

- Extending the degree to which the analysis focuses on the distribution of characteristics instead of average crew characteristics.
- Accounting for the characteristics of equipment operators who are not responsible for equipment maintenance.
- Considering the possibility of selectivity bias if allocation of personnel to ships depends on the ships' characteristics.
- Using a flexible model that permits the estimation of elasticities of personnel substitution.*

---

* The elasticity of substitution is a measure of the proportionate change in the ratio of marginal products of two inputs for a proportionate change in the input ratio, defined here as

$$\sigma_{ij} = -\frac{d\ln(X_i/X_j)}{d\ln(MP_i/MP_j)} .$$

Large positive elasticities indicate that inputs can easily be substituted for each other. A zero value implies that no substitution can take place, i.e., the inputs need to be used in fixed proportions.

A FLEXIBLE MODEL FOR RELATING UNIT PERFORMANCE TO PERSONNEL CHARACTERISTICS

Here we present a model and some preliminary empirical work that incorporate many of the suggestions from the preceding discussion. To examine the productivity and substitutability of personnel with different characteristics, a model that permits the estimation (rather than the definition) of substitution elasticities is needed. The generalized Leontief production function [6] is such a model:

$$Q = \sum_{i=1}^{n} a_{ii} X_i + \sum_{\substack{i=1 \\ i \neq j}}^{n} \sum_{j=1}^{n} a_{ij} X_i^{1/2} X_j^{1/2} . \tag{1}$$

Q denotes output and X_i and X_j are services or inputs. Equality of a_{ij} and a_{ji} $(i \neq j)$ is necessary for estimation. If cross-product terms are ignored, (1) is simply a linear production function and a_{ii} is strictly positive.

The marginal product of input X_i is:

$$f_i = \frac{dQ}{dX_i} = a_{ii} + \sum_{\substack{j=1 \\ j \neq i}}^{n} \frac{1}{2} a_{ij} \left(\frac{X_j}{X_i} \right)^{1/2} . \tag{2}$$

Since quantity indexes for capital are neither available nor easy to construct, they are not included in this analysis. We chose to examine mental groups as the labor categories. We assume that increasing the use of capital would proportionally raise or lower the marginal product of all mental groups equally.

The Leontief production function was applied to data from OpNav Notice C3700, "Flight Activity of Naval Aircraft," June 1973 to December 1980, on 46 deployments of fighter and attack squadrons. The measure of output was the quarterly average of the mission capable (MC) rate, the percentage of operating aircraft that are at least partially mission capable. The input variables were the numbers of squadron enlisted personnel in mental groups 1 or 2, 3, and 4.

The marginal products of the three mental group categories and the elasticities of substitution between them were calculated. For squadron maintenance personnel, the increase in the mission capable rate from the addition of one more enlisted man in mental group 1 or 2 was twice the increase from the addition of one more enlisted man in mental group 3. Relative to mental groups 1 through 3, the increase from the addition of one more enlisted man in mental group 4 was nil. The elasticities

indicated that adjacent mental groups were substitutes for each other but the highest and lowest groups were not. These results are only suggestive, coming from the first 46 of nearly 600 squadron deployments for which data are available.

Future work could use the data from all squadrons and evaluate additional substitutions: first-termers versus careerists, high school graduates versus nongraduates, A-schoolers versus on-the-job trainees, and combinations of them.

Coincident with the research relating unit characteristics to unit performance has been research on measures of individual productivity derived from questionnaire and survey data. It is to this second type of research on personnel trade-offs that we now turn.

PERSONNEL PRODUCTIVITY MEASURED BY SURVEYS

Our objective here is to determine the pitfalls and potential of questionnaires and surveys for measuring personnel productivity. The military studies we will examine all use expert opinion to arrive at measures of personnel productivity.

PREVIOUS WORK

B-K Dynamics [7] and Decisions and Designs [8] asked Navy experts to estimate the utility of an average enlisted man as he progressed through his career. The B-K Dynamics study found that junior officers placed a greater emphasis on experience than senior officers did, and that the differences between utility estimates across ratings were negligible.

The Decisions and Designs study used interviews with senior officers and enlisted men to measure "accrued utility," the additional contribution a person makes to a job as a result of training beyond initial skill training and of job experience. Accrued utility varied greatly by rating.

Neither study defined utility clearly and unambiguously. Neither explicitly recognized that a person is usually part of a work unit and that his productivity may depend on the unit's composition.

One of the earliest studies of personnel trade-offs that took unit composition into account was conducted by the Institute of Naval Studies at CNA [9]. Experienced Navy supervisors were asked how many enlistees they had on board in a given rating and experience class (basic, apprentice, journeyman, and chief). Then they were asked to think about alternative force configurations — how current effectiveness could be maintained with different numbers and experience classes of personnel. Unfortunately, many supervisors made one-to-one trade-offs between adjacent experience classes, reflecting either a true one-to-one trade-off or difficulty in thinking about fractions of enlistees.

B-K Dynamics [7] attempted to circumvent the fractional enlistee problem by having experienced supervisors specify a preferred team of enlistees for a work situation. Then the supervisors estimated changes in effectiveness due to small changes in the make-up of the preferred team. But because the team make-up was characterized by both paygrade and experience levels, they were required to examine some unlikely trade-offs. Many supervisors ignored such extreme comparisons and were excluded from the analysis because the production function could not accommodate implied zero effectiveness. A possible solution to the problem might have been to assume that within a paygrade all levels of experience were substitutable for each other.

The Rand Corporation [10] used Enlisted Utilization Survey (EUS) data on Air Force personnel to examine trade-offs between career and first-term personnel. (EUS data was first used to analyze the optimal mix of formal schooling and on-the-job training for different ratings [11].) The EUS was a survey of first-term personnel in specific ratings at their first duty stations betwen November 1974 and January 1975. The supervisors of these personnel rated their "net contribution to unit production" relative to the "average specialist with four years' experience" at four points during a first enlistment.

Productivity estimates for each work unit were aggregated, and the experience mix of the work unit was computed. Since the survey solicited productivity estimates for only the first four years of service, it was assumed that an individual's productivity thereafter was constant. Even with this assumption, which downwardly biases the value of careerists, the study showed that the Air Force could maintain current personnel productivity at lower cost with proportionally more careerists.

The elasticities of substitution between first-termers and careerists ranged from nearly 1 to 9 according to specialty, indicating that potential for substitution existed. Specialties with longer training times, the more technical ones, had the lower elasticities of substitution.

Although the survey method relies on subjective judgment, its careful application in conjunction with appropriate models can advance the measurement of personnel productivity. We propose to use the EUS data on the Navy in a new model to measure the growth in productivity of first-term personnel by rating. Once these curves are estimated, we can use the information to evaluate first term/career trade-offs, first-term contract length, and rating assignments. Before examining these applications, however, a discussion of the estimation procedure is appropriate.

A MODEL FOR MEASURING GROWTH IN PERSONNEL PRODUCTIVITY

To measure the growth in productivity of recruits with four-year obligations, we will use productivity assessments from the EUS of over 7,000 Navy personnel. This information will be used to generate productivity curves within ratings for individuals with different characteristics. The curves will measure an individual's net productivity relative to the average specialist with four years of experience. They can also be understood as learning curves that identify the rate of skill acquisition from apprentice to average fourth-year specialist.

Different ratings generally require different amounts of training and have different rates of skill acquisition. In the civilian sector, these differences have often been identified with the slope of the

earnings-experience profile: occupations with large training components have steeper earnings profiles than occupations with smaller amounts of on-the-job learning.* The variety of Navy ratings suggests differences in training between them and, hence, in the growth of productivity within them. While a seaman six months out of boot camp may be as productive as a fourth-year seaman, a Hospital Corpsman six months out of A-school is unlikely to be as productive as a fourth-year Hospital Corpsman.

In the civilian sector, we could verify this intuition by examining the earnings profile.** Because this procedure will not work in the military, we have to conceptualize differences in the growth of cost and productivity for individuals in different ratings. The marginal product of an individual is the change in total unit output that accompanies his presence. It is negative if the individual's contribution to output is less than the output lost due to the need to supervise on-the-job trainees. As an illustration, a seaman (whose training time is very short and whose productivity on the job increases rapidly to a "trained" level) is contrasted with a petty officer in an advanced electronics rating (whose formal training is lengthy and whose productivity growth takes place over a longer period). Whether and where the cost and marginal product curves cross — the general location of cost relative to marginal product — are empirical questions.***

---

* See [12] for a seminal discussion of these relationships.

** It is an oversimplification to suggest that a glance at an age-earnings profile for a civilian worker allows one to determine the training component of the job. Work by Lazear [13] with implicit contract theory suggests the lack of a unique relationship between the growth of earnings and the growth of productivity.

*** CNA has done research on this topic [14]. A survey of 1900 senior petty officers compared the costs of on-the-job training (OJT) only with a combination of A-school and OJT. Each petty officer was asked: 1) to estimate how long it took the average trainee to reach third class in his rating, 2) to plot the average trainee's productivity relative to those qualified to take the third class exam during each month of OJT, and 3) to estimate how much supervisory time was spent instructing on-the-job trainees. Generalized learnings curves were calculated and the costs evaluated as we propose doing. However, the EUS data are more recent and on an individual level.

To answer these questions, we will estimate relative productivity for representative Navy ratings by ordinary least squares regression:

Productivity relative to average specialist with 4 years' experience = f (months since completion of formal training (M), M^2, mental group, education, race, sex, age)

Then we will calculate training costs for the ratings. For each individual quality type in each rating, the costs of training at time T are:

$$C_{iT} = \int_0^T \left[O_{it} + W_{it} - (\bar{W}_5)(R_{it}) \right] dt ,$$

where

- i = an index of the individual quality type (by schooling and mental group)
- t = an index of the month, $t = 1,48$
- C_{iT} = total cost of training the i-th quality type at time T
- O_{it} = other costs for the i-th quality type in the t-th month (boot camp, A-school, C-school)
- W_{it} = average wages paid to the i-th quality type in the t-th month
- $\bar{W}_5$ = average fifth-year wages, including any bonuses. This indexes the dollar value of output to the wage of individuals beginning their second term.
- R_{it} = relative productivity of the i-th quality type at time t, e.g., the net marginal productivity of this individual quality type relative to the productivity of an average specialist with four years' experience. This information will be obtained from the relative productivity regression.

To find the costs expended on training by the 15th month, for example, we subtract the value of the individual's output from his wages and any formal training costs over the 15 months.

We will identify the productivity of a four-year specialist with his compensation. A strong interpretation is that a specialist in his fifth year is fully productive and his compensation (wage plus bonuses) reflects the value of his output to the Navy. A weaker interpretation is that the assumption is a reasonable approximation.

Training costs will be calculated by rating for different quality types and for A-school graduates/nonattendees. This should facilitate cost comparisons between the two methods of training, on-the-job versus a combination of formal schooling and on-the-job training.

Figure 1 illustrates hypothetical training cost curves for A-school graduates of different quality types within a particular rating. Costs of training increase at least until formal training ends, assuming that no output is produced during formal training. The costs of training the less able individual are assumed to be larger. The less able individual may take longer to complete A-school or may take more supervisory time after A-school or in on-the-job training. Training costs begin to fall when the individual's output is greater than the output lost in training him.

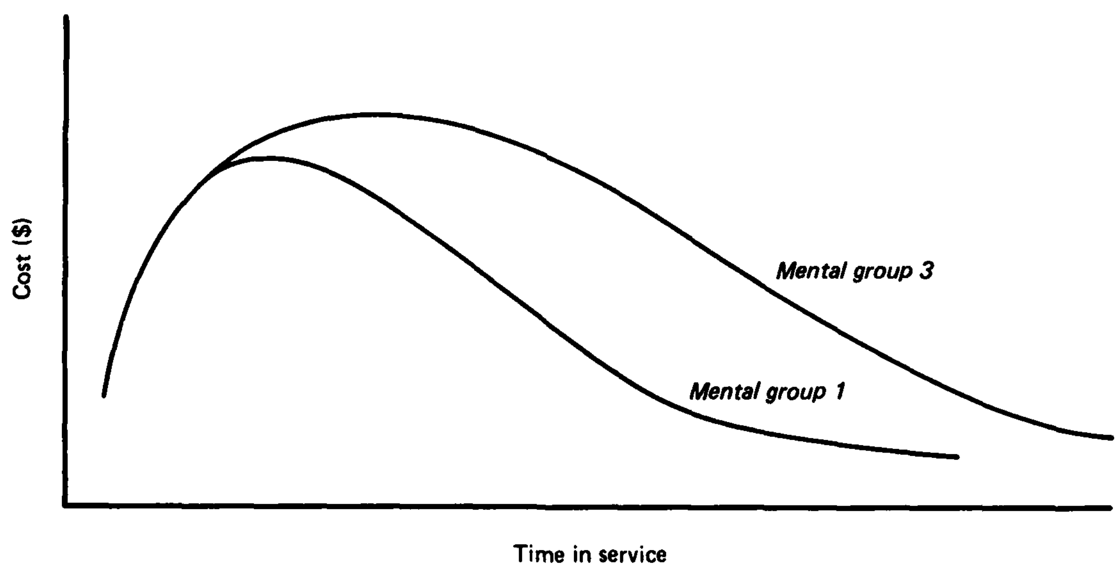

FIG. 1: HYPOTHETICAL TRAINING COST CURVES

To understand better what the cost estimates mean, it is important to distinguish the costs of training from the measurement of the value of training itself. While we propose to measure the training costs incurred by the Navy, we do not propose to analyze or measure OJT. OJT

is the difference between the individual's actual output and the output he would produce if he spent no time training in that period. We have no information on how much an individual would produce if he stopped training and devoted all of his time to production. This is the case because we have no explicit information on supervisory costs and other opportunity costs involved in OJT. The information we do have is the observed growth of net productivity, wages, and formal training costs. From this we can calculate the Navy's training costs, but we cannot evaluate OJT as such.

We can, however, answer some questions about whether the Navy is at least recouping its training costs over the four-year enlistment period.* For the Navy, the question we address is: after 48 months, how does the output generated compare with the costs incurred?

Knowledge of how long it takes different individuals in a rating to become fully productive should greatly improve our ability to find least-cost manpower solutions for the Navy. As the following section illustrates, one use is to evaluate the costs of attrition more accurately.

A SCREEN MODEL BASED ON PRODUCTIVITY AND SURVIVAL

We propose to integrate the information on rating-specific learning curves with the information derived from survival curves, such as those used by CNA to construct SCREEN tables utilized by Navy recruiters [15]. These tables evaluate survival probabilities for individuals of different quality types (mental group, high school graduate or not, age, etc.) and establish eligibility cutoffs.

The "state of the art" chooses recruits on the basis of an analysis that measures the area under a survival curve to determine the expected months of service for a recruit [15]. However, it may mask important information on attrition patterns, because the early months of service, when a recruit is less productive, are weighted equally to later months, when he is more productive. A weighting scheme is needed that takes productivity over time into account.

* This discussion is in the spirit of Lazear's work on retirement [13]. He argues that firms may underpay workers early in their careers and overpay them later to encourage stability in their work forces. The implicit contract, that wage payments will eventually exceed marginal products, combined with a mandatory retirement age makes the system work. Contracts untie the simultaneous relationship between the wage and marginal product, requiring only equalization of the discounted streams over the contract period.

Figure 2 illustrates a survival curve superimposed on a hypothetical productivity profile. The value to the Navy of a recruit can be calculated as:

$$V = \int_0^T \phi\,(x:t)P(x:t)dt \;, \tag{1}$$

where ϕ is a survival density function and P is our productivity estimate, both of which are functions of time (t) and recruit characteristics (x).

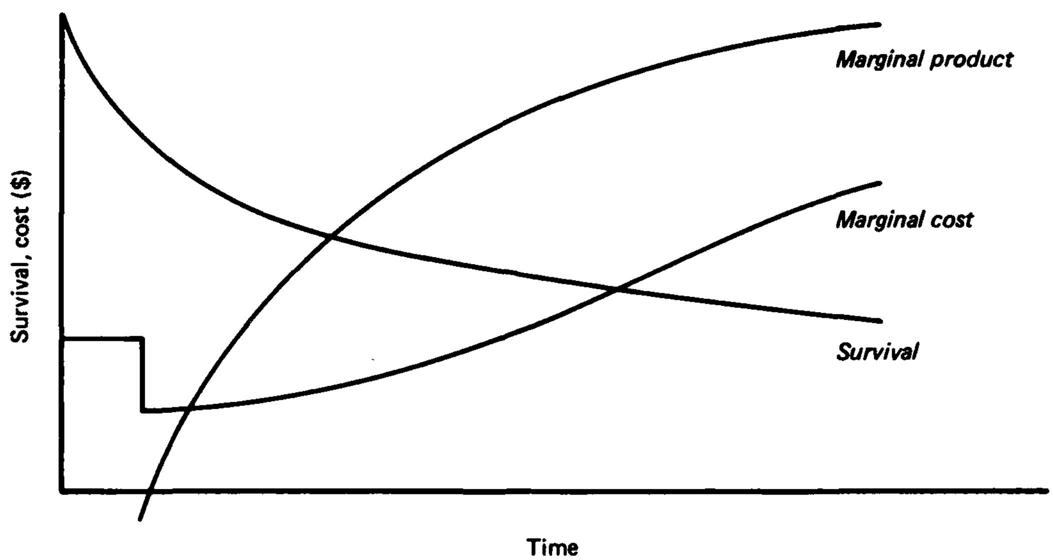

FIG. 2: COST, PRODUCTIVITY, AND SURVIVAL CURVES

Figure 2 also illustrates a marginal cost curve. If cost data are sufficiently precise, and if productivity can be converted into dollar measures, then they can be added to the calculation of value. Net value to the Navy is defined as:

$$NV = \int_0^T \phi(x:t)\;[P(x:t) - C(x:t)]dt - RC(x)\;. \tag{2}$$

This calculation takes account of the marginal cost of a recruit (C), which depends upon time and recruit characteristics, and such fixed costs as recruiting cost (RC), which depends only upon individual characteristics.

To convert productivity assessments into dollars, some strong assumptions, discussed in the previous section, are necessary. An alternative approach is to estimate a cost equation independent of productivity, such as:

$$C = \int_0^T \phi(x:t)\ C\ (x:t)dt + RC(x)\ . \tag{3}$$

These estimates can be compared with estimates from equation 1, which are measured in units of productivity rather than dollars. Then for two types of recruit, i and j, the Navy can maximize its output by a recruiting policy such that

$$\frac{V_i}{V_j} = \frac{C_i}{C_j}\ . \tag{4}$$

Estimation of equations 2 and 3 may be difficult but, in a simplified form, equation 1 can be estimated. This type of analysis still provides easily interpretable results for use in SCREEN-type tables, contains more information than current measures, and combines information on productivity and survival in a simple manner.

EXTENSIONS OF THE MODELS

The findings of our proposed analyses could be integrated with the CNA Navy Comprehensive Compensation and Supply (NACCS) model, a cost-minimization model to meet fixed manpower requirements at the fifth year of service. The costs associated with not being fully productive can be added to the costs of recruit training and the costs of A-school in the NACCS model. Lacking estimates of the costs of OJT, the NACCS study could not treat OJT as a decision variable (trade-offs between A-school and OJT) or exploit differences in OJT costs across ratings in the assignment of recruits with different attrition probabilities. Our proposed analysis can provide this missing information. Finally, the estimates of the productivity of first-termers relative to that of individuals beginning their second term would enable us to examine efficient first-term/career force mixes.

There are several other refinements and extensions that can increase the usefulness of our approach. CNA has developed a novel way of jointly estimating survival and advancement [16]. Other studies have indicated that productivity is a function of both experience and paygrade [5, 8]. Combining the work in [16] with productivity estimates that control for both experience and advancement could further refine our estimates of the expected value of a recruit to the Navy.

CNA has also shown that there are differences across ratings in the first-term survival of different types of recruits [17]. The analysis only examined the effect of assignment on retention. It did not consider the productivity of different kinds of people in different jobs. In the productivity studies cited, we have noted significant differences across ratings in the growth of productivity with experience. Assignments to ratings based on both productivity and retention are clearly feasible, although a large amount of additional analysis would be involved.

More generally, information on the rate of skill acquisition by rating is crucial for analyses of most important productivity-related questions. Any examination of the proper contract length, the proper mix of careerists and first-termers, and the efficient determination of manpower requirements needs information on productivity by rating.

Since the measures of personnel productivity used in this section rely on supervisory evaluations, we plan to validate findings by using more objective measures. Unit performance, addressed in an earlier section of this report, is one such measure. Another is the measure of individual performance suggested in the next section.

PERSONNEL PRODUCTIVITY MEASURED BY INDIVIDUAL PERFORMANCE

CNA studies [15, 18, 19, 20] have successfully predicted enlisted survival from recruit education, mental group, and age. But what is the relationship of recruit productivity to these personal characteristics? We chose performance on standardized advancement examinations as a measure of productivity and estimated its relationship to the characteristics of those taking the examinations.

For paygrades E-4 through E-7, eligibility to take advancement-in-rating examinations is determined by time in rate, time in service, successful completion of required course work, a set of practical tests, and recommendation of commanding officer.* The examination results, along with performance marks, credits for awards, and longevity factors, are made into a composite to provide an ordering of the candidates. This ordering enables the Navy to select the most-qualified individuals in meeting requirements for the next higher paygrade.

The scores on advancement examinations should reflect knowledge or skill level in the rating and should vary by personal characteristics. To test this hypothesis, we used data for the Hospital Corpsman (HM) E-4 exam and ordinary least squares regression to estimate parameters of an equation relating exam score to personal characteristics. Table 1 shows the characteristics of the HMs.

Results are reported in table 2. The intercept is the predicted score for an HM who is not a high school graduate, is in mental group 4, and is nonwhite. The coefficients give the change in expected score due to possession of the particular characteristic. The largest and most significant effects are those for the top two mental groups. However, these results are not directly useful for comparison with SCREEN effects, because they are subject to selection bias.

There are two sources of selection bias in the exam score estimation: not all eligible candidates choose to take the exam, and only survivors have an opportunity to take it. A relatively simple method of correcting for selection bias has been suggested [21]. Essentially, it involves including in the estimation equation a correction parameter derived from a separate estimation of the probability of being in the omitted subsample. In our case, two correction factors are needed. They are calculated from probit regression estimates of the probability of not surviving and the probability of taking the exam. The procedure for calculating correction factors and the detailed probit results are presented in [22].

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* A small percentage of personnel receive early advancement without examination owing to performance in school or participation in special programs; they are not included in our analysis.

TABLE 1

SELECTED CHARACTERISTICS OF HM PERSONNEL
TAKING E-4 ADVANCEMENT EXAM IN MARCH 1980

Characteristic	Mean value
Test score[a]	49.5
Education:	
Less than high school diploma	.05
GED certificate	.07
High school diploma	.81
Beyond high school	.07
Mental group:[b]	
1 (AFQT 93-99)	.02
2 (AFQT 65-92)	.47
3U (AFQT 49-64)	.34
3L (AFQT 31-48)	.12
4 (AFQT 10-30)	.05
Race:	
White	.79
Nonwhite	.21

[a]Navy standard scores are calculated by norming raw examination scores to a mean of 50 and standard deviation of 10.
[b]Mental group categories are based on AFQT scores renormed using 1981 standards.

TABLE 2

PARAMETER ESTIMATES FOR
PREDICTING HM ADVANCEMENT EXAM SCORES

Characteristic	Coefficient	t-value
Race = white	4.10	6.02
Education:		
GED	0.24	0.15
High school diploma	1.19	1.00
Beyond high school	6.09	3.90
Mental group:		
1	14.79	6.90
2	8.90	6.54
3U	3.71	2.70
3L	0.41	0.27
Intercept	39.31	--
Number of observations	1206	
$\bar{R}^2$	.18	

The results with corrections for selection bias are reported in table 3. Comparison with table 2 shows that the corrections have little effect on the size and significance of the race, mental group, and GED coefficients. However, they change considerably the coefficient for high school diploma, actually reversing its sign. They also reduce the size of the coefficient for education beyond high school. The conclusion is that mental group is the best predictor of performance as measured by advancement exam scores.

This analysis suggests that measures of individual performance could enhance recruit classification and rating assignment. If our results are validated for other ratings and other measures, tables could be developed in which the weights attached to personal characteristics for screening and assignment purposes incorporate productivity as well as survival predictions.

TABLE 3

PARAMETER ESTIMATES FOR PREDICTING HM ADVANCEMENT EXAM SCORES: CORRECTED VERSION

Characteristic	Coefficient	t-value
Race = white	4.10	5.88
Education:		
GED	-0.74	-0.47
High school diploma	-1.66	-1.06
Beyond high school	3.48	1.86
Mental group:		
1	13.82	6.33
2	7.61	5.16
3U	2.27	1.46
3L	-0.02	-0.00
λ_1 correction factor from survival probit[a]	-6.66	-2.61
λ_2 correction factor from test sample probit[a]	5.66	1.51
Intercept	39.31	
Number of observations	1206	
$\overline{R}^2$	.19	

[a]Described in [22].

PROPOSALS FOR ADVANCING THE MEASUREMENT OF PERSONNEL PRODUCTIVITY

Research on the productivity of personnel is necessary if the Navy is to maximize total output from a limited manpower budget. We have reviewed several approaches to the measurement of productivity, comparing the advantages and disadvantages of each. What are the implications for the direction of future research?

We believe that the appropriate way to attack the measurement of personnel productivity is along a broad front. To this end, we propose a number of output measures, either available at CNA or readily obtainable, that could be related to education, mental ability, experience, and training:

(1) Quarterly data on flights, Mission Capable Rates, and other measures of unit performance are available for all Naval aviation squadrons. Earlier we described a flexible model that relates these measures to squadron personnel characteristics. Refinements based on additional measures of equipment condition, supply, and training can provide insight into interactions among the personnel characteristics.

(2) Detailed information on equipment failures and maintenance was collected for F-14, S-3, and P-3 squadrons and individual aircraft as part of the CNA study of wartime spares policy. This data set can be used to assess the productivity of maintenance personnel.

(3) Data on mission performance from VP squadrons provide specific performance measures for flights that emphasize operational performance rather than training. The data cover flights by both active and reserve crews, which would allow analysis of their comparative effectiveness. Data from simulators could also be used.

(4) The relations among training, experience, exercise performance, and wartime effectiveness for F-14 pilots and radar intercept officers could be studied. Training would be measured by the number of flight hours and the number of previous exercises. Performance would be measured by the number of intercepts in fleet air defense exercises, and the exchange ratio in air combat maneuver exercises. The effect of training on performance would be developed from detailed reconstructions of exercises, including discussions with participants. Once the effect on performance in exercises is estimated, a model developed in CNA's Non-Nuclear Threat Ordnance Study would be used to estimate the effect on wartime performance. This type of analysis could dramatically display the effects of personnel and training expenditures on wartime outcomes.

(5) Extensive data on the material condition of ships in the FF-1052 and DDG-2 classes were collected and analyzed in CNA's Ship Overhaul Effectiveness Study. Expansion of this work to place greater

emphasis on personnel factors can provide additional information on the effectiveness of maintenance personnel.

(6) Operational Readiness Inspection scores have been studied by CNA as a measure of performance. The general findings could be validated with current data and a flexible model that estimates substitution possibilities among personnel groups. These data provide a singular opportunity to analyze standardized operational exercises.

(7) Navy data from the DoD Enlisted Utilization Survey are being analyzed. This data set matches evaluations of supervisors with detailed information on the education, ability, and training of individual first-term personnel. The Navy data can provide information on the growth of productivity over time for first-term personnel; moreover, improvements in empirical methods will allow estimation of the relative effects of education and AFQT scores on productivity. A survey that extends coverage to careerists could also be carried out.

(8) Measures of individual performance based on job-specific components of advancement exams provide another avenue for productivity research. Earlier we presented a model that used advancement exam scores as a proxy for performance. To test the value of scores as a proxy, actual performance ratings of aviation ASW operators from the VP squadron data cited above could be used.

Pursuing several complementary lines of research should enable us to determine the directions that are most promising for future research. Consistent findings across several lines of work will lead to policy prescriptions for improving personnel distribution and requirements determination.

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